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Slope Stability Assessment for State Highways in Berkshire County, Massachusetts

By Pamela Patrick, PE, PG; Daniel Kobzar, EIT; David Posner, EIT; James Roy; Andrea Daly; and Mi-Hyun Park, PhD

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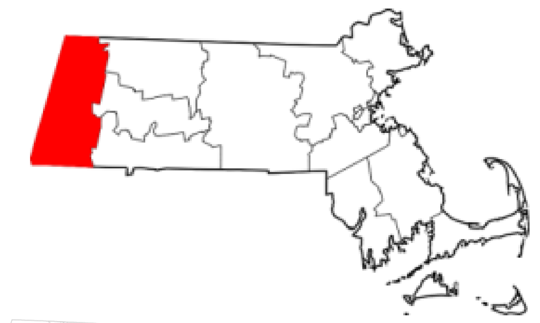

Abstract

This study is aimed to identify areas along state arterial highways that could present a hazard for a landslide and erosion in the event of a major storm. The study areas focused on the state roads located within Berkshire County, Massachusetts, which is expected to have significant variations in topography. A scoring system was developed to evaluate the slope stability hazard based on slope, flood potential and soil properties. The result shows a color-coded prioritized map of the areas of high, moderate, and low hazards, which highlight the areas of highest priority based on their relative hazards. This will assist in budgeting and urban planning with regard to erosion control, landslide mitigation, and repairs, as warranted. Therefore, our results can be used for decision support system for transportation road management.

Introduction

The objective of this study conducted at the University of Massachusetts Amherst was to identify potentially problematic landslide areas along state arterial highways in Berkshire County, Massachusetts. The specific state roads of interest were Routes 2, 7, 8, 9, and 20. The overarching aim of the study was to provide Berkshire County with a landslide analysis, and identify and flag areas that might warrant further investigation. This analysis will help in budgeting and urban planning with regard to erosion control, landslide mitigation, and repairs, as warranted.

The area of study, Berkshire County, was selected because of the features of the region. The hilly topography allowed for a wide variation in soil slope angles. Berkshire County also has a distribution of both rural and urban areas, which was useful in the economic risk analysis. There are a large number of streams in Berkshire County, which allows for a variety of flood zones to affect soil stability. With these features combined, Berkshire County was a relevant area for the project that would project a wide variety of analyses and results.

Methods

Information was compiled to account for surficial geology, slope angle, risk of flooding, degree of runoff, and economic impact for areas within the buffer zone (i.e. in close proximity to the highway).

A scoring system was then developed in order to produce an explicit yet efficient means of qualitatively comparing the areas included in the buffer zone with regard to landslide hazard. In this manner, four individual georeferenced data layers were overlaid for the purpose of developing the final score. These layers include: Surficial Geology, NRCS SSURGO-Certified Soils by Slope, FEMA National Flood Zones, and Urban Boundaries. Each of these layers were available for the entire Commonwealth of Massachusetts through MassGIS, however, information outside of the buffer zone (200 m from centerline) was neglected for the purpose of this investigation. The scoring system is summarized in **Table 1** and the following equation.

Table 1: Summary of Scoring System

Category	Low Hazard	Moderate Hazard	High Hazard
Slope Angle	0% - 8%	8% - 15%	15% - 35%
Score:	0 – 1	3	5 -10
FEMA Flood Zone	D	X500	A, AE, ANI, AO
Score:	1	5	10
Surficial Geology	Till & Bedrock	Alluvium	Sand & Gravel
Score:	1	5	10

Final Score = (Urban Factor) X (Slope Score+ FEMA Score + Geology Score)

Note: Slope Score, FEMA Score, and Geology Score are applied in accordance with Boolean logic based on the point system presented in Table 1. Urban Factor was 1.0 for areas outside of the Urban Boundary and 1.2 for areas within the Urban Boundary (light gray shaded regions).

This data was then exported to Microsoft Excel. All of the columns except for the attributes used for scoring and "FID" were deleted. For each attribute, a worksheet was created with a table that gave a score for each possible value of that particular attribute, in accordance with **Table 1.**

The VLOOKUP function in Excel was used to link the scores to the main workbook. This function does much the same thing as the "join" operation in ArcGIS. Each input attribute value is looked up in the appropriate table, and the designated point value is returned. A new column was created and filled with a formula to add together three of the scores ("SlopeScore", "Floodscore", and "GeoScore", as provided in **Table 1**) and multiply that sum by the "UrbanScore". The resulting values became the "FinalScore". All remaining null values were replaced with zeroes or other designated characters.

Finally, the main workbook was imported to ArcGIS and joined to the Union table by FID value. The range of final scores was from 3 to 36. Scoring was displayed graphically, 1-6.9 points displays green, 7-14.9 points displays yellow and above 15 points displays red. In this manner, the symbology were set up to display a color based on the value of the "FinalScore" such that "low hazard" areas were green, "moderate hazard" areas were yellow, and "high hazard" areas were red. This visual display of risk makes quick interpretation of the results easier, and can be understood by a layman. This is summarized in **Table 2.**

Table 2: Output of Scoring System

FinalScore	Qualitative Hazard	Color Code for Final Map	Priority for Further Investigation
15+	High	Red	High
7 – 14.9	Moderate	Yellow	Moderate
3 – 6.9	Low	Green	Low

Results and Discussion

The results of the scoring application for the North Adams example area is presented in **Figure 1.** The results provided in **Figure 1** indicate that North Adams is an urban zone, with varying scores in, slope angle, flood zone, and surficial geology. (Refer to **Figures 2, 3, and 4**, respectively).

The same scoring technique was applied to the entire county, although the results are more visible on a city-wide scale than county-wide scale. Results for the entirety of Berkshire County are provided in **Figure 5**.

The results of this study generally resemble, but do not exactly match those of the Berkshire County Hazard Mitigation Plan. (See **Figure 6**.) The Berkshire County Hazard Mitigation Plan indicated that the northwest corner of the state has a high susceptibility to landslides, though they do admit there is a low occurrence. There are some different data sets and assumptions made by this study. Namely they worked with snow melt data, river erosion and rock falls. They did not appear to use urban zones as a factor. There was no available information on the exact means of calculation, just the results and some information on factors involved.

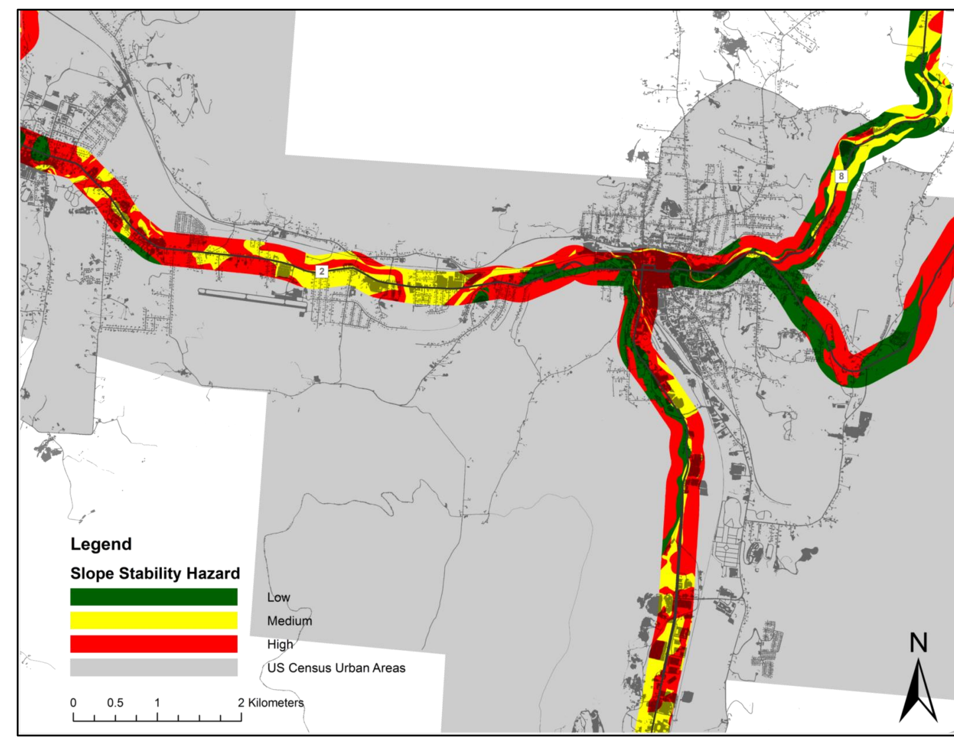

Figure 1: Results for North Adams, MA

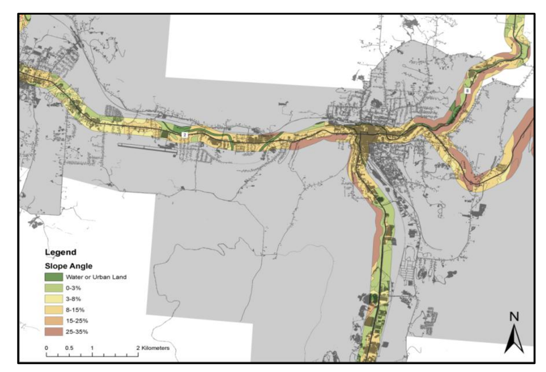

Figure 2: Slope Angle North Adams, MA

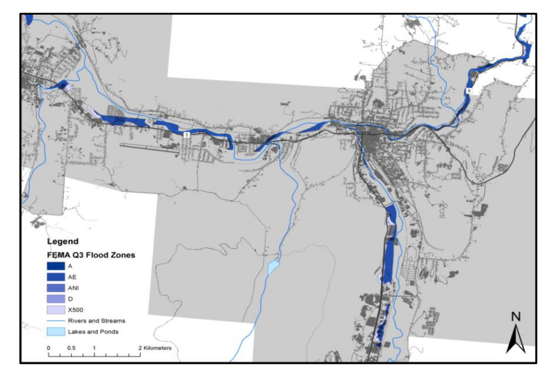

Figure 3: FEMA Flood North Adams, MA

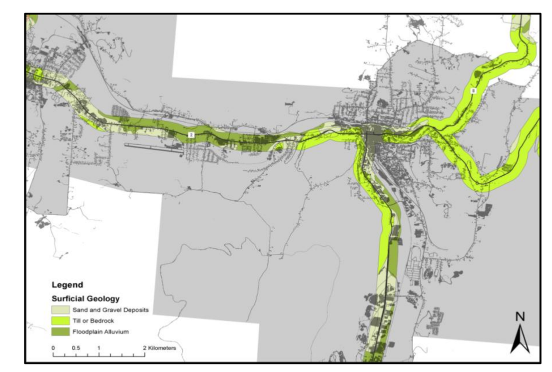

Figure 4: Surficial Geology North Adams, MA

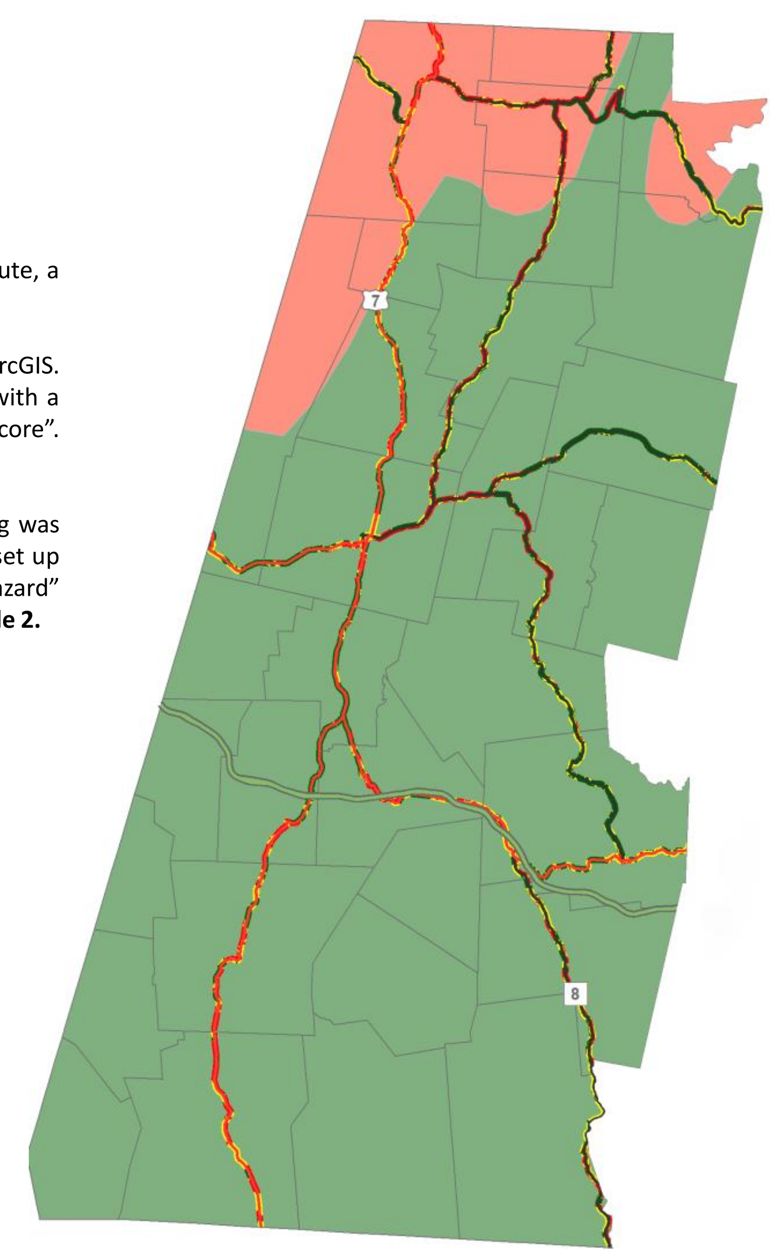

Figure 6: Comparison with Existing Study

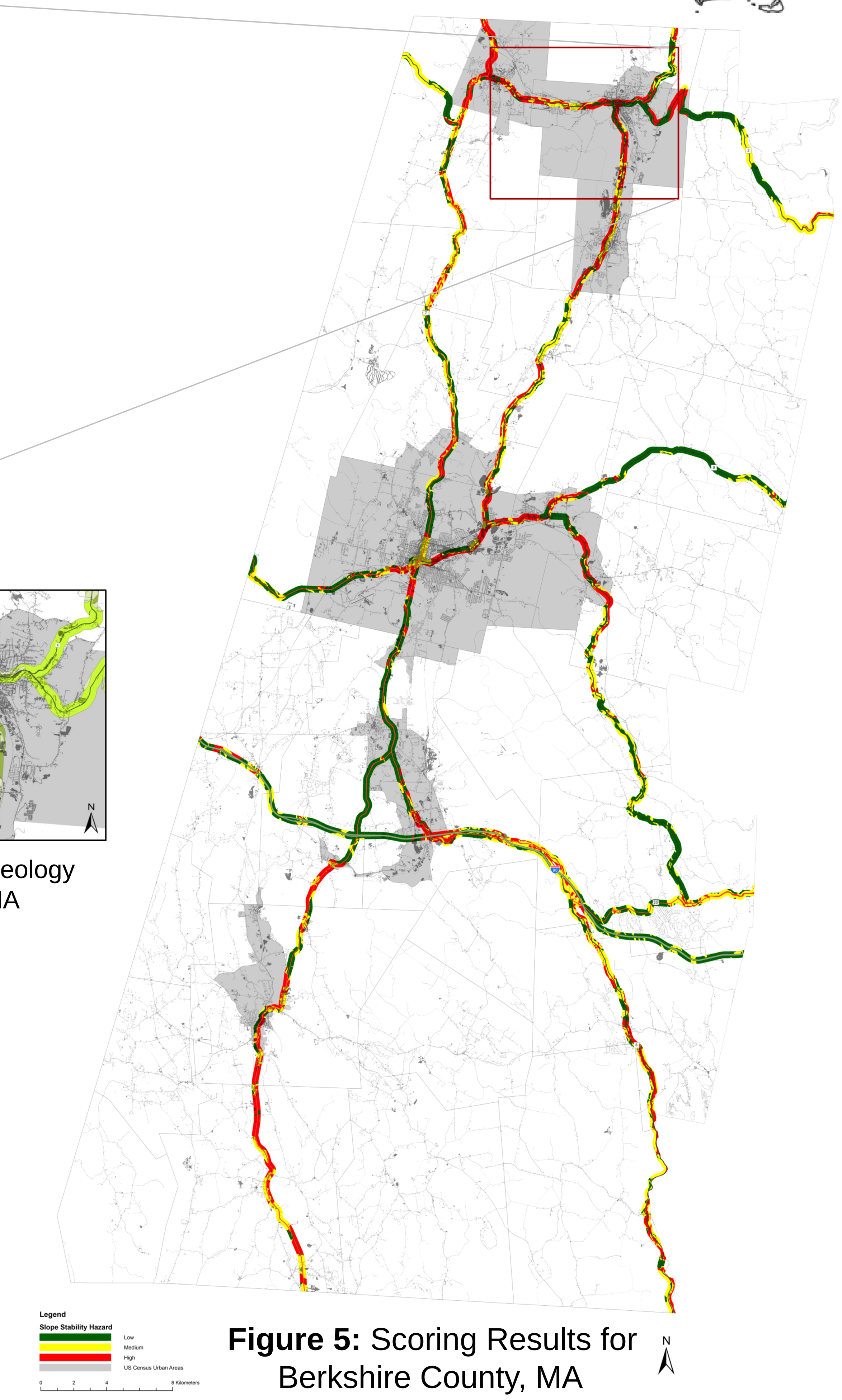

Figure 5: Scoring Results for Berkshire County, MA

Recommendations for Further Studies

There are several opportunities for further studies and refinement of these analyses. A common type of slope failure in Berkshire County is rock fall. This type of slope failure was beyond the scope of these analyses. Geotechnical data that would help predict instability risk for rock fall could be available, or could be derived from other data. With data on runoff routing, ArcGIS could predict risk zones on a much more precise scale. Storm data for 25 and 50 year storms could be used to predict more common or less consequential instability risks.

Conclusion

In conclusion, ArcGIS proved to be an efficient tool to combine and analyze slope stability and erosion hazards. It minimized time and labor, as compared to traditional field techniques. The results are useable and realistic for the purpose of prioritizing those areas which should warrant further investigation by MassDOT for landslide and erosion hazards. This analysis could easily be modified to use on any area with similar available data.

References

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